

NESTING ECOLOGY OF ARCTIC LOONS

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The Pacific Arctic Loon (*Gavia arctica pacifica*) nests in tundra and boreal forest regions of North America and northeast Siberia and is commonly found wintering along the Pacific coast of North America from the Gulf of Alaska to Baja California (Bent 1919, Dement'ev and Gladkov 1951, Palmer 1962). Information on the nesting ecology of Arctic Loons in North America is limited to a study at the McConnell River Delta, Northwest Territories (Davis 1972), a study at Storkersen Point, Alaska (Bergman and Derksen 1977), and incidental observations from other areas (Brandt 1943, Bailey 1948, Sutton and Parmalee 1956, Parmalee et al. 1967, Chiles 1969). Most information on nesting ecology is from European and Asian subspecies (*G. a. arctica* and *G. a. viridigularis*) (Gilroy 1923, Dement'ev and Gladkov 1951, Lindberg 1968, Sjölander 1968, Lehtonen 1970, Dunker and Elgmork 1973, Dunker 1974).

This study was designed to investigate the adaptations of the Arctic Loon in western Alaska to the tundra pool habitat. Specific objectives were to determine the habitat used by Arctic Loons during the breeding season, to observe reproductive success, and to evaluate factors influencing reproductive success.

STUDY AREA AND METHODS

A study area of 12.3 km² was established on the Clarence Rhode National Wildlife Range on the Yukon-Kuskokwim River Delta, Alaska (61°26'N, 165°26'W), about 24 km from the coast of the Bering Sea (see Mickelson 1975 for detailed description). The land vegetation types on the study area were wet marsh tundra and heath tundra as described by Holmes and Black (1973). The study area contained 266 lacustrine ponds varying from 0.2 ha to 100 ha, and averaging 1.5 ha in size. Most ponds were 0.5–1.5 m deep and contained small islands of the type used by nesting waterfowl and loons.

Loon nests were found by searching shorelines and wading to islands. All ponds were searched for nests prior to or during the time the eggs hatched, and twice thereafter for the presence of adults and young. Arctic Loon nests found without eggs or egg remains were considered to be nests which had contained eggs since Common Loons (*Gavia immer*) do not build a complete nest platform until the first egg is laid (Olson and Marshall 1952). Observations of the nesting behavior of Arctic Loons have verified that assumption (Petersen 1976). Laying dates of eggs for most nests were estimated by egg flotation (Westerkov 1950), or by interpolation from the dates of hatching. Sizes of ponds and distances between nests were measured from aerial photographs.

RESULTS

Spring phenology and loon arrival.—The ponds and river systems were covered with a complete layer of ice on my arrival on 3 May 1974, and on

TABLE 1
PHENOLOGY OF SPRING ICE MELT

Event	1974	1975
River with open leads	4 May	30 May
River ice-free	26 May	15 June
Sloughs draining meltwater	5 May	27 May
Ponds with meltwater	6 May	26 May
All ponds 90% or more ice-free	23 May	5 June

2 May 1975. Snow cover was also complete at this time in 1975, but most of the ground was bare in early May in 1974. Melting of ice and snow was later in 1975 than in 1974, but proceeded faster in 1975 than in 1974 (Table 1).

Arctic Loons were first observed on 5 May 1974, and 12 May 1975, with peak arrival dates of 23 May 1974, and 29 May 1975. Previous arrival data of Arctic Loons in an area within 9.6 km of the study area were: 12 May 1969 and 1970, and 23 May 1971 and 1972 (Mickelson 1973), and 17 May 1973 (C. P. Dau, pers. comm.). Pairs occupied the ponds (46 of 52 observations) as soon as sufficient meltwater or open water was available to enable the bird to take-off from them (6 May 1974, and 26 May 1975).

Nests and nest-sites.—Nineteen and 60 pairs of Arctic Loons nested on the study area in 1974 and 1975, respectively. Nests were oval in shape and made of materials from the vicinity of the nest. Nest-sites were categorized as one of 4 types: (1) islands which were surrounded by water during the entire nesting season; (2) drying islands which were surrounded by water at initiation of the clutch, but became connected to shore prior to hatching; (3) wet shore nests which were at the edge of emergent vegetation; or (4) dry shore nests. Although the total number of nests in the study area varied widely between the years, the use of shore and island nest-sites did not differ significantly ($\chi^2 = 1.53$, 1 df, NS). Most nests were

TABLE 2
ARCTIC LOON NEST-SITES

Year	Number of nests			
	Island	Drying island	Wet shore	Dry shore
1974	9	2	6	2
1975	21	4	30	5
Total	30 (38%)	6 (8%)	36 (46%)	7 (9%)

TABLE 3
DISTRIBUTION¹ AND DISTANCES BETWEEN ARCTIC LOON NESTS

Year	Number	Distance (m)		R	σ_{re}	C	P
		Mean \pm SE	Range				
1974	18	386 \pm 41	134–590	1.218	0.034	2.029	0.0424
1975	58	297 \pm 14	134–590	1.641	0.012	9.667	0.0001

¹ R is the measure of the degree the observed distribution deviates from random (R = 1 in random distribution, R = 0 in maximum aggregation, and R = 2.149 in uniform distribution); C is the standard variant of the normal curve; P is the level of significance (Clark and Evans 1954).

along wet shore, followed in frequency by nests on islands, dry shore and drying islands (Table 2).

Ponds with nests averaged 1.8 ± 0.4 ha (range 0.3–7.0 ha, N = 19) in size in 1974 and 1.8 ± 0.2 ha (range 0.3–9.6 ha, N = 60) in size in 1975. Only 2 ponds (<1%) on the study area were greater than 9.6 ha, and 24% were less than 0.3 ha.

Nests were evenly spaced in both years (Table 3), with straight line distances between nests averaging 23% greater in 1974 than 1975 ($t = 2.60$, 74 df, $P < 0.02$).

Clutch-size and chronology.—Clutch-sizes in 33 of the 79 nests could not be determined because predation had occurred before the nests were found. Forty-three nests contained 2 eggs and 3 contained 1 egg, for an average clutch-size of 1.93. The female from a nest containing 1 egg was collected 3 days after laying. She had 2 ruptured ovarian follicles, demonstrating that she had laid 2 eggs, 1 of which was not found. Possibly all of the loon nests had contained 2 eggs, and the other 1-egg clutches reflected the effects of partial predation.

Few dates of egg-laying could be estimated in 1974 because of almost complete destruction of clutches before the nests were found. Egg-laying occurred in 2 nests on 29 May and 2 June, respectively, 7 and 11 days after the peak arrival of pairs on ponds. In 1975 initiation of 36 clutches oc-

TABLE 4
DATES OF ARCTIC LOON EGG DESTRUCTION 1975

Status of eggs	Number of nests observed		
	4–18 June	19 June–3 July	4–20 July
Whole eggs	32	11	0
Eggs destroyed	10	23	8

TABLE 5
HATCHING SUCCESS OF ARCTIC LOONS BY NEST-SITE 1975

Nest fate	Location of nests		
	Island No. (%)	Drying island and wet shore No. (%)	Dry shore No. (%)
Successful	11 (52.4)	7 (20.6)	1 (20.0)
Destroyed	10 (47.6)	27 (79.4)	4 (80.0)

curred between 4–22 June with 50% of the nests begun by 9 June, 11 days after the peak arrival of pairs on ponds. Egg-laying was probably begun only about 7 days later in 1975 than in 1974.

Hatching success.—Only 1 of 19 nests (5%) hatched on the study area in 1974. In this nest 1 egg hatched on 25 June. At least 1 egg in 19 of 59 nests (32%) hatched in 1975. The first egg hatched on 1 July and the peak of hatching occurred on 4 July. All young hatched by 6 July, although the laying dates for 36 clutches indicated that 47% of the clutches should have hatched between 7 and 19 July. Two eggs hatched in 7 of the 19 (37%) successful nests, with the second egg hatching within 2 days of the first egg.

Exact dates of egg destruction could not be determined for most nests in 1974, but the contents of 3 of the 9 nests observed between 2 and 17 June, and 5 of 6 nests observed between 18 June and 4 July had been destroyed. This suggests that predation became heavier later in the incubation period and for nests initiated later as was obvious in 1975 ($\chi^2 = 28.08$, 2 df, $P < 0.005$; see Table 4).

Nests on islands were more successful than nests located in other sites in 1975 ($\chi^2 = 6.41$, 1 df, $P < 0.05$; see Table 5), although only 36% of the nests were on islands (Table 2). Island nest-sites were not established earlier than other types of nests ($\chi^2 = 0.91$, 3 df, NS).

Eggs were observed being destroyed only when human activity near the nest forced an adult off a nest for several hours and a Long-tailed Jaeger (*Stercorarius longicaudus*) and a Parasitic Jaeger (*Stercorarius parasiticus*) each ate 1 egg (D. G. Raveling, pers. comm.). Eggs from 3 nests were gathered by Eskimos for food. Glaucous Gulls (*Larus hyperboreus*) and Parasitic and Long-tailed jaegers nested in the study area and were frequently observed. Red foxes (*Vulpes fulva*) were commonly observed, and 1 arctic fox (*Alopex lagopus*) was seen. However, the species of predator that destroyed each loon egg was generally undetermined. Glaucous Gulls normally eat eggs at the nest, but occasionally may fly away from a nest with whole eggs before eating them. Jaegers normally eat eggs at a nest

TABLE 6
ARCTIC LOON NEST-SITE AND EVIDENCE OF PREDATION

Year	Appearance of destroyed nests	Number of nests			
		Island	Drying island	Wet shore	Dry shore
1974	Fragments	1	1	3	2
	Without fragments	3	1	1	0
	Unknown	5	0	0	1
1975	Fragments	5	3	5	0
	Without fragments	5	0	15	4
	Human destruction	0	0	3	0

(Mickelson 1975) and, if eggshells remain in a nest, loons may remove them and drop them into the water (Olson and Marshall 1951, Hall and Arnold 1966, and von Braun et al. 1968). Foxes remove eggs from the vicinity of a nest before eating or caching them (Tinbergen 1972), but fox tracks were rarely discernible in the vegetation.

Nonetheless, the evidence of the type of predation at different nest-sites (Table 6) varied significantly in 1975. Egg remains were found most often in, or near, island and drying island nest-sites, and nests without egg remains were predominantly shore nest-sites ($\chi^2 = 9.58$, 3 df, $P < 0.025$). This suggest that jaegers and gulls were primarily responsible for destruction of nests on islands, and foxes caused most of the destruction of those on shores. Data from 1974 are insufficient for testing differences by nest-site. However, the overall proportion of destroyed nests with egg remains to those without, was similar in both years ($\chi^2 = 2.02$, 1 df, NS).

DISCUSSION AND CONCLUSIONS

Factors influencing arrival and nest initiation.—Arctic Loons used the first available open ponds in spring. In the year in which ponds were available when loons arrived (1974) they were used immediately. In the late year (1975) loons were observed before ponds were available, but they only occupied ponds as soon as sufficient water was available. Thus, the timing of migration was not adjusted to compensate for the early or the late year, and may coincide with normal or average dates of availability of water areas. More data are needed for confirmation of this conclusion.

Lehtonen (1970) and Davis (1972) suggest that Arctic Loons wait for water levels to decline before laying eggs. Nest-sites were available by 18 May 1974, when Arctic Loons arrived, but loons did not begin laying until 29 May. Ponds in the spring of 1975 had dry shores by 1 June, but loons did not initiate nests until 4–22 June. Loons did not lay eggs when nest-

sites were first available, suggesting that the delay in laying eggs is not necessarily a direct result of the availability of nest-sites.

Grau (1976) has shown that by counting the number of dark and light rings of the yolk after staining, the length of time for yolk formation can be estimated. An insufficient sample of loon eggs ($N = 1$) has been adequately examined, however, the similar-sized Cackling Goose (*Branta canadensis minima*) requires 12 days for yolk formation (Grau 1976). Yolk formation in the Arctic Loon may be initiated when the birds arrive on the nest pond, as the delay of egg-laying is about the same duration as the suspected time of development of the yolk. Such a delay is an adaptation to a widely fluctuating arctic environment, where ponds necessary for nesting may or may not be available when birds arrive. Shore and island nest-sites are not available until after water levels have declined in the ponds, usually several days after the pond has open water. The delay of egg formation insures that suitable nesting habitat will be available when the egg is ready to be laid and prevents the loss of eggs that might otherwise occur.

Factors influencing hatching success of Arctic Loons.—Hatching success appeared to be influenced most significantly by predation, which could be altered by nest-site selection, the timing of nesting, the type of predator, and the availability of alternate prey. In 1974, when 95% of nests were destroyed, hatching success was not related to the type of nest-site selected. In 1975, nest-site selection was an important factor in hatching success. The significantly higher success of pairs nesting on islands (Table 5) seems to represent selection pressure for loons to nest on islands. Although islands were available in 83% of the ponds used by nesting loons ($N = 68$), only 53% of the nests were located on islands. Of 43 ponds with shore nests, 38 (88%) contained 1 or more islands apparently suitable for nesting when loons began laying eggs, yet islands were not used.

The high rate of nest destruction by predators in 1974 may have resulted from a lack of alternate prey. Only 3 tundra voles (*Microtus oeconomus*) were seen during the entire 1974 field season, in contrast to daily observations of voles in 1975. Red foxes were frequently seen in both years, in contrast to 1 observation from 1969–1972 by Mickelson (1975) on an adjacent study area. Jaegers and Glaucous Gulls were almost always in evidence and apparently did not nest in 1974, but did in 1975.

The most abundant nesting waterfowl on the study area was the Cackling Goose. In 1974, Glaucous Gulls, jaegers, and red foxes destroyed 64% of 95 Cackling Goose nests (D. G. Raveling, unpubl. data), in contrast to a 33% average over 4 years recorded by Mickelson (1975). The 1974 modal hatching date of Cackling Goose eggs was 23 June with 93% hatching by 28 June. No Arctic Loon nest which would have had eggs hatch after 25

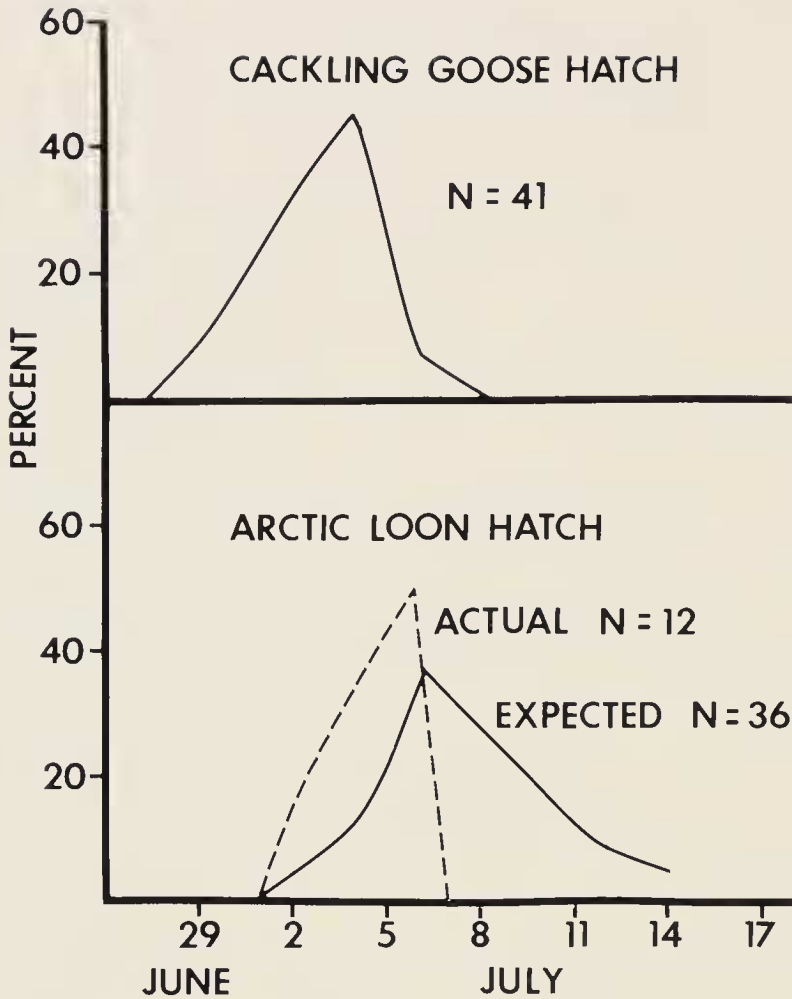


FIG. 1. Hatching dates of Cackling Goose and Arctic Loon eggs in 1975.

June was successful. In 1975, the modal hatching date of Cackling Goose eggs was 3 July, with all eggs hatching by 7 July. Arctic Loon eggs began hatching 1 July and should have continued hatching to 19 July, but none hatched after 6 July at which time the goose hatch was essentially complete (Fig. 1).

Jaegers and gulls commonly flew over ponds and apparently successfully found and destroyed cryptic loon eggs, especially in 1974, but this occurred primarily after the hatching of the creamy colored goose eggs which had been a common food source for jaegers. Combined island and shore nesting by loons may reflect an adaptive response by loons to varying predation pressures—by jaegers and gulls on islands and foxes along shorelines. In years of low or average fox density and average or high jaeger density, shore nesting may be favored. Conversely, when jaeger numbers or their taking of eggs is low, island nesting may be favored. In years of high combined avian and mammalian predation, density and pressure, and low vole density, such as 1974, Arctic Loons were almost totally unsuccessful.

Because of predation pressure, the timing of Arctic Loon and Cackling Goose hatching dates was an important factor in reproductive success of the Arctic Loon. Cackling Geese will normally be hatching before the majority of Arctic Loons because of their 11-day earlier nest initiation (Mickelson 1975, Raveling, unpubl. data), and shorter incubation period (26 vs 28 days) even though they lay eggs over a 4- to 6-day period, in contrast to the initiation of incubation with the laying of the first egg by loons. Arctic Loon eggs became the most abundant large eggs on the study area after the geese hatched. Heavy predation on loon eggs occurred late in incubation, when adults were less likely to leave the nest, than early in incubation. Davis (1972), at the McConnell River Delta, also noted an increase in predation on loon eggs when the eggs of nearby colonial Blue Geese (*Anser caerulescens caerulescens*) were hatching, but did not note if the increased predation pressure was significant.

SUMMARY

Arctic Loons were studied on the Yukon-Kuskokwim Delta, Alaska, from the time of their arrival in May to their departure in September, in 1974 and 1975. Pairs arrived on breeding ponds as soon as sufficient meltwater was available to allow their take-off and landing. Loons apparently do not initiate nests immediately after their arrival, even when nest-sites are available. Delayed egg-laying may be dependent on a period of yolk formation. Delaying yolk formation until after arrival on nest ponds is an adaptation by loons to the variable time suitable habitat becomes available for nesting.

Predation of eggs by Glaucous Gulls, Long-tailed and Parasitic jaegers and foxes varied in relation to the location of the nest-site, and the availability of alternate prey. Hatching success was the lowest recorded for Arctic Loons (5%) in 1974, when eggs of both loons and Cackling Geese were taken in large numbers by predators. Hatching success increased to 32% in 1975 when an abundance of tundra voles was observed. No loon eggs hatched after the hatching of the Cackling Goose eggs when this alternate prey was no longer available. Nests destroyed by foxes were predominantly along shorelines, and those by gulls and jaegers were predominantly on islands. Nest-site selection by Arctic Loons may reflect an adaptive response to varying selective pressures by their predators.

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LITERATURE CITED

- BAILEY, A. M. 1948. Birds of arctic Alaska. Colorado Mus. Nat. Hist. Pop. Series. No. 8.
- BENT, A. C. 1919. Life histories of North American diving birds. U.S. Natl. Mus. Bull. 107.
- BERGMAN, R. D. AND D. V. DERKSEN. 1977. Observations on Arctic and Red-throated loons at Storkersen Point, Alaska. *Arctic* 30:41-51.
- BRANDT, H. 1943. Alaska bird trails. The Bird Research Foundation, Cleveland, Ohio.
- CHILES, H. E., JR. 1969. Birds and mammals of the Pitmegea River Region, Cape Sabine, Northwestern Alaska. Biol. Pap. Univ. Alaska, No. 10.
- CLARK, P. J. AND F. C. EVANS. 1954. Distance to nearest neighbor as a measure of spatial relationships. *Ecology* 35:445-453.
- DAVIS, R. A. 1972. A comparative study of the use of habitat by Arctic Loons and Red-throated Loons. Ph.D. thesis, Univ. Western Ontario, London, Ontario.
- DEMENT'EV, G. P. AND N. A. GLADKOV (EDS.). 1951. Birds of the Soviet Union, Vol. 2 (trans. from Russian). Israel Program for Scientific Translations, Jerusalem, Israel.
- DUNKER, H. 1974. Habitat selection and territory size of the Black-throated Diver, *Gavia arctica* (L.), in south Norway. *Norw. J. Zool.* 22:15-29.
- AND K. ELGMORK. 1973. Nesting of the Black-throated Diver, *Gavia arctica* (L.) in small bodies of water. *Norw. J. Zool.* 21:33-37.
- GILROY, N. 1923. Field-notes on the nesting of divers. *Br. Birds* 12:318-321.
- GRAU, C. R. 1976. Ring structure of avian egg yolk. *Poult. Sci.* 55:1418-1422.
- HALL, A. B. AND G. P. ARNOLD. 1966. Brief observations on a pair of Red-throated Divers (*Gavia stellata*) nesting in East Greenland. *Dansk Ornithol. Forenings Tidssk.* 60:141-145.
- HOLMES, R. T. AND G. P. BLACK. 1973. Ecological distribution of birds in the Kolomak River-Askinuk Region, Yukon-Kuskokwim Delta, Alaska. *Condor* 75:150-163.
- LEHTONEN, L. 1970. Zur Biologie des Prachttauchers, *Gavia a. arctica* (L.). *Ann. Zool. Fenn.* 7:25-60.
- LINDBERG, P. 1968. Något om Storlommens (*Gavia arctica* (L.)) och Smålommens (*Gavia stellata* L.) ekologi. *Zool. Revy* 30:83-88.
- MICKELSON, P. G. 1973. Breeding biology of Cackling Geese (*Branta canadensis minima* Ridgway) and associated species on the Yukon-Kuskokwim Delta, Alaska. Ph.D. thesis, Univ. Michigan, Ann Arbor, Mich.
- . 1975. Breeding biology of Cackling Geese and associated species on the Yukon-Kuskokwim Delta, Alaska. *Wildl. Monogr.* 45:1-35.
- OLSON, S. T. AND W. H. MARSHALL. 1952. The Common Loon in Minnesota. *Occ. Pap. Minn. Mus. Nat. Hist.*, No. 5.
- PALMER, R. S. (ED.). 1962. Handbook of North American Birds. Vol. 1. Yale Univ. Press, New Haven, Connecticut.
- PARMALEE, D. F., H. A. STEPHENS AND R. H. SCHMIDT. 1967. The birds of southeastern Victoria Island and adjacent small islands. *Nat. Mus. Canada Bull.* No. 222.
- PETERSEN, M. R. 1976. Breeding biology of Arctic and Red-throated loons. M.S. thesis, Univ. Calif., Davis, California.
- SUTTON, G. M. AND D. F. PARMALEE. 1956. On the loons of Baffin Island. *Auk* 73:78-84.
- TINBERGEN, N. 1972. Food hoarding by foxes (*Vulpes vulpes*). (1965) Pp. 315-328 in *The animal in its world* (N. Tinbergen). Harvard Univ. Press, Cambridge, Massachusetts.

- VON BRAUN, C., A. HESSLE AND S. SJÖLANDER. 1968. Smålommens (*Gavia stellata* P.) beteende under ungvårdnadstiden. Zool. Revy 30:94-95.
- WESTERKOV, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56-67.

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Errata.—Vol. 91, No. 1, "Song differences and map distances in a population of Acadian Flycatchers" by R. B. Payne and P. Budde. An error in placing of decimals affects the numbers in Tables 1 and 2, p. 33. Values for characters 7 through 11 should be multiplied by 0.1 to correct the min, max, and means. The values for SD are also affected, but the values for CV and the results of the principal component analysis and the clustering analysis are not affected by the change.—R. B. Payne.

"Red-shouldered Hawk nesting ecology and behavior" by J. W. Portnoy and W. E. Dodge. On p. 104 the scientific name for Bald Eagle should read *Haliaeetus leucocephalus*.

Vol. 91, No. 2, "Effects of pine-oak clearcutting on wintering and breeding birds in southwestern Virginia" by R. N. Conner et al. On p. 307, Table 1, the scientific name of the Carolina Wren should read *Thryothorus ludovicianus*.

Vol. 91, No. 3, "Blue-winged × Cinnamon Teal hybrid from Oklahoma" by E. G. Bolen. On p. 367 the scientific name of the Cinnamon Teal should read *Anas cyanoptera*.

Vol. 91, No. 2, "Experiments on population regulation in two North American parids" by F. B. Sampson and S. J. Lewis. On p. 225, para. 3, line 7, the first BFL 2 should read BFL 1. On p. 227, the ANOVA used should read 1-way ANOVA.